

## 6.0 BIBLIOGRAPHY

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## **TABLES**

TABLE 2-1

## Artificial Recharge Methods

Recharge Method		Recharge Water Source	Constaints	Benefits	Relative Cost
Wells		Treated Peak Flows	Cloggin, Need suitable aquifer, water quality	May be able to retrofit existing wells	High
Surface Infiltration	Spreading Basins	Larger area needed, Peak flows, Stormwater,	Unconfined aquifers, surface flooding	Inexpensive, could use existing gravel pits in favorable areas	Low-Moderate
	Dry Wells	Peak flows, Stormwater, Treated Wastewater	Unconfined aquifers	Small area, can be localized	Moderate
	Wetlands	Peak flows, Stormwater, Treated Wastewater	Unconfined aquifers, connection with groundwater system, surface flooding	May provide some additional treatment	Moderate

Summary of Groundwater Anti-Degradation Criteria and Hoh River Water Quality

	Constituent	Anti-Degradation Criteria	Hoh River Data <sup>a</sup>			Units	Comment
			Minimum	Maximum	Average		
Primary Contaminants	Barium*	1				mg/L	
	Cadmium*	0.01				mg/l	
	Chromium*	0.05				mg/l	
	Lead*	0.05				mg/l	
	Mercury*	0.002				mg/l	
	Selenium*	0.01				mg/l	
	Silver*	0.05				mg/l	
	Fluoride	4				mg/l	
	Nitrate (as N)	10	<0.01	0.45	0.10	mg/l	Analysis of Nitrate+Nitrite
	Endrin	0.0002				mg/l	
	Methoxychlor	0.1				mg/l	
	1,1,1-Trichloroethane	0.2				mg/l	
	2,4 D	0.1				mg/l	
Secondary Contaminants	2,4,5-TP Silvex	0.01				mg/l	
	Total Coliform Bacteria	1/100	<1	280	13	CFU/100 ml	Analysis of fecal coliform
	Copper*	1				mg/l	
	Iron*	0.3				mg/l	
	Manganese*	0.05				mg/l	
	Zinc*	5				mg/l	
	Chloride	250				mg/l	
	Sulfate	250				mg/l	
	Total Dissolved Solids	500				mg/l	
	Foaming Agents	0.5				mg/l	
	pH	6.5 to 8.5	6.40	8.20	7.41	s.u.	
	Corrosivity	noncorrosive				-	
	Color	15	0	64	12	color units	
Radionuclides	Odor	3				TON	
	Gross Alpha Particle Activity	15				pCi/l	
	Gross Beta Particle Radioactivity						
	Gross Beta Activity	50				pCi/l	
	Tritium	20,000				pCi/l	
	Strontium-90	8				pCi/l	
Carcinogens	Radium 226 & 228	5				pCi/l	
	Radium -226	3				pCi/l	
	Acrylamide	0.02				µg/L	
	Acrylonitrile	0.07				µg/L	
	Aldrin	0.005				µg/L	
	Aniline	14				µg/L	
	Aramite	3				µg/L	
	Arsenic*	0.05	<0.1	0.5	0.28	µg/L	Total Recoverable Analyses
	Azobenzene	0.7				µg/L	
	Benzene	1				µg/L	
	Benzidine	0.0004				µg/L	
	Benzo(a)pyrene	0.008				µg/L	
	Benzotrichloride	0.007				µg/L	
	Benzyl chloride	0.5				µg/L	
	Bis(chloroethyl)ether	0.07				µg/L	
	Bis(chloromethyl)ether	0.0004				µg/L	
	Bis(2-ethylhexyl) phthalate	6				µg/L	
	Bromodichloromethane	0.3				µg/L	
	Bromoform	5				µg/L	
	Carbazole	5				µg/L	
	Carbon tetrachloride	0.3				µg/L	
	Chlordane	0.06				µg/L	
	Chlorodibromomethane	0.5				µg/L	
	Chloroform	7				µg/L	
	4 Chloro-2-methyl aniline	0.1				µg/L	
	4 Chloro-2-methyl aniline hydrochloride	0.2				µg/L	
	o-Chloronitrobenzene	3				µg/L	
	p-Chloronitrobenzene	5				µg/L	
	Chlorthalonil	30				µg/L	
	Diallate	1				µg/L	
	DDT (includes DDE and DDD)	0.3				µg/L	
	1,2 Dibromoethane	0.001				µg/L	
	1,4 Dichlorobenzene	4				µg/L	

Summary of Groundwater Anti-Degradation Criteria and Hoh River Water Quality

	Constituent	Anti-Degradation Criteria	Hoh River Data <sup>a</sup>			Units	Comment
			Minimum	Maximum	Average		
	3,3' Dichlorobenzidine	0.2				µg/L	
	1,1 Dichloroethane	1				µg/L	
	1,2 Dichloroethane (ethylene chloride)	0.5				µg/L	
	1,2 Dichloropropane	0.6				µg/L	
	1,3 Dichloropropene	0.2				µg/L	
	Dichlorvos	0.3				µg/L	
	Dieldrin	0.005				µg/L	
	3,3' Dimethoxybenzidine	6				µg/L	
	3,3 Dimethylbenzidine	0.007				µg/L	
	1,2 Dimethylhydrazine	60				µg/L	
	2,4 Dinitrotoluene	0.1				µg/L	
	2,6 Dinitrotoluene	0.1				µg/L	
	1,4 Dioxane	7				µg/L	
	1,2 Diphenylhydrazine	0.09				µg/L	
	Direct Black 38	0.009				µg/L	
	Direct Blue 6	0.009				µg/L	
	Direct Brown 95	0.009				µg/L	
	Epichlorohydrin	8				µg/L	
	Ethyl acrylate	2				µg/L	
	Ethylene dibromide	0.001				µg/L	
	Ethylene thiourea	2				µg/L	
	Folpet	20				µg/L	
	Furazolidone	0.02				µg/L	
	Furium	0.002				µg/L	
	Furmecyclo	3				µg/L	
	Heptachlor	0.02				µg/L	
	Heptachlor Epoxide	0.009				µg/L	
	Hexachlorobenzene	0.05				µg/L	
	Hexachlorocyclohexane (alpha)	0.001				µg/L	
	Hexachlorocyclohexane (alpha) (technical)	0.05				µg/L	
	Hexachlorodibenzo-p-dioxin, mix	0.00001				µg/L	
	Hydrazine/Hydrazine sulfate	0.03				µg/L	
	Lindane	0.06				µg/L	
	2 Methoxy-5-nitroaniline	2				µg/L	
	2 Methylaniline	0.2				µg/L	
	2 Methylaniline hydrochloride	0.5				µg/L	
	4,4' Methylene bis(N,N'-dimethyl) aniline	2				µg/L	
	Methylene chloride (dichloromethane)	5				µg/L	
	Mirex	0.05				µg/L	
	Nitrofurazone	0.06				µg/L	
	N-Nitrosodiethanolamine	0.03				µg/L	
	N-Nitrosodiethylamine	0.0005				µg/L	
	N-Nitrosodimethylamine	0.002				µg/L	
	N-Nitrosodiphenylamine	17				µg/L	
	N-Nitroso-di-n-propylamine	0.01				µg/L	
	N-Nitrosopyrrolidine	0.04				µg/L	
	N-Nitroso-di-n-butylamine	0.02				µg/L	
	N-Nitroso-N-methylethylamine	0.004				µg/L	
	PAH	0.01				µg/L	
	PBBs	0.01				µg/L	
	PCBs	0.01				µg/L	
	o-Phenylenediamine	0.005				µg/L	
	Propylene oxide	0.01				µg/L	
	2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.0000006				µg/L	
	Tetrachloroethylene (perchloroethylene)	0.8				µg/L	
	p,α,α,α-Tetrachlorotoluene	0.004				µg/L	
	2,4 Toluenediamine	0.002				µg/L	
	o-Toluidine	0.2				µg/L	
	Toxaphene	0.08				µg/L	
	Trichloroethylene	3				µg/L	
	2,4,6-Trichlorophenol	4				µg/L	
	Trimethyl phosphate	2				µg/L	
	Vinyl chloride	0.02				µg/L	

## Notes:

a. Data from [http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=2003&tab=final\\_data&scroll=558&wria=20&sta=20B070](http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?theyear=2003&tab=final_data&scroll=558&wria=20&sta=20B070)

Blank cells: no data

\*metals are measured as total metals

TABLE 2-3

## Surface Water Source Limitation Letters

<b>Water Body</b>	<b>Letter Date</b>	<b>Recommendation</b>
Beaver Creek (tributary to Sol Duc River)	9-Dec-92	Recommended denial of application for 0.6 cfs, recommended no diversions when flow < 215 cfs October-June or flow <145 cfs July-September
Bogachiel River (tributary to Quillayute River)	12-Sep-91	Denial of application, concerns for Coho salmon
Lake Pleasant (tributary to Sol Duc River)	31-Mar-93	Denial of application, concerns for Coho salmon
Sol Duc River (tributary to Quillayute River)	27-Feb-92	Denial of application, concerns for Coho salmon
Sol Duc River (tributary to Quillayute River)	5-May-89	Recommended low flow provisions of 250 cfs October-June and 145 cfs July-September measured at Snider Creek Ranger Station Gage
Snider Creek (tributary to Sol Duc River)	11-Jan-93	Recommended low flow provisions of 215 cfs October-June and 145 cfs July-September measured at Snider Creek Ranger Station Gage (Sol Duc River)



TABLE 2-4

## Summary of Evaluated Areas

Area		Approximate Aquifer Thickness (feet)	Approximate Well Yields (gpm)	Potential Recharge Water Source(s)	Positives for Artificial Storage	Uncertainties for Artificial Storage	Groundwater Supply Potential	Artificial Recharge Potential
Forks Prairie		10 to 15	5 to 400	Treated wastewater, stormwater, peak flows	<ul style="list-style-type: none"> <li>Moderately permeable and confined aquifers</li> <li>Water quality is generally good</li> </ul>	<ul style="list-style-type: none"> <li>Extent of aquifer</li> <li>Continuity with Calawah and Bogachiel Rivers</li> <li>Amount of available aquifer capacity</li> </ul>	Moderate-High	Moderate
Quillayute Prairie		5 to 20	<5 to 70	Peak flows	<ul style="list-style-type: none"> <li>Moderately permeable and confined aquifer(s)</li> </ul>	<ul style="list-style-type: none"> <li>Extent of confined aquifer</li> <li>Continuity with Quillayute and Sol Duc Rivers (and adjacent shallow alluvial aquifers)</li> <li>Amount of available aquifer capacity</li> </ul>	Moderate	Moderate
Three Rivers		10 to 30	<5 to 300	Peak flows	<ul style="list-style-type: none"> <li>Moderately to highly permeable aquifer(s)</li> <li>High permeability = Limited interference between wells</li> </ul>	<ul style="list-style-type: none"> <li>Lateral extent of sand and gravel aquifer</li> <li>Continuity with the Quillayute, Sol Duc and Bogachiel Rivers, potential for Groundwater Under the Direct Influence of Surface Water (GUI)</li> <li>Potential for salt water intrusion near tidally influenced Quillayute River</li> <li>Pumping capacity of aquifers</li> </ul>	Moderate-High	Low-Moderate
Lower Hoh		5 to 20	<5 to 100	Peak flows	<ul style="list-style-type: none"> <li>Moderately permeable and confined aquifer(s)</li> <li>Areas of known groundwater discharge (springs) that could support wells</li> </ul>	<ul style="list-style-type: none"> <li>Lateral extent of permeable outwash sand and gravel</li> <li>Saturated thickness of the permeable sand and gravel</li> <li>Continuity with the Hoh River</li> <li>Water quality (low pH, high Fe/Mn)</li> <li>Amount of available recharge</li> </ul>	Low-Moderate	Low
Upper Hoh	Groundwater Development	5 to 10(?)	10 to 40(?)	Peak flows	<ul style="list-style-type: none"> <li>Pumped water would be returned to stream - no net impairment to streamflow</li> </ul>	<ul style="list-style-type: none"> <li>Hydrogeologic conditions in the Upper Hoh area are uncertain.</li> </ul>	Low-Moderate	Low-Moderate(?)
	Augmentation of Streamflow with Groundwater					<ul style="list-style-type: none"> <li>Aquifer area is limited to the Hoh River valley (&lt; 1 mile wide). Pumping of high-capacity wells would likely induce recharge from the river in a relatively short time, reducing flows in the river</li> <li>Hydrogeologic conditions in the Upper Hoh area are uncertain. Well yields may be less than 500 gpm and a number of wells would be required to supply the desired augmentation quantities</li> <li>Estimated costs for the wells may be significantly higher because of site access and preparation and the distance to suitable electrical service</li> </ul>		
	Augmentation of Streamflow with Bank Storage				<ul style="list-style-type: none"> <li>Augmenting streamflow will help maintain productivity of salmon runs</li> </ul>	<ul style="list-style-type: none"> <li>A surface water diversion structure will need to be constructed and maintained</li> <li>A conveyance structure from the diversion point to the recharge area will be needed (abandoned side channel, canal, or transmission main)</li> <li>Lag time between recharge and seepage back to the stream may be too short to provide significant benefits during the desired augmentation period</li> </ul>		
	Augmentation of Streamflow with Surface Water Storage					<ul style="list-style-type: none"> <li>Actual augmentation flows, duration and frequency need to be determined</li> <li>Difficulty in reservoir permitting</li> <li>The geotechnical suitability of any proposed location has to be confirmed</li> </ul>		
Beaver/Lake Pleasant		1 to 40	1 to 60	Peak flows, induced recharge from lake	<ul style="list-style-type: none"> <li>Moderately permeable aquifer(s)</li> <li>Aquifer is confined</li> </ul>	<ul style="list-style-type: none"> <li>Lateral extent of the outwash sand and gravel aquifer(s)</li> <li>Continuity of the aquifer(s) with the Lake Pleasant and the Sol Duc River, potential for Groundwater Under the Direct Influence of Surface Water (GUI)</li> <li>Amount of available aquifer capacity</li> <li>Pumping capacity of the aquifer(s)</li> <li>Water availability for Lake Pleasant sockeye</li> </ul>	Low-Moderate	Low - Moderate
Ozette/Trout Creek *		1 to 10(?)	1 to 10	Peak flows, induced recharge from lake	<ul style="list-style-type: none"> <li>Two storage options: bank storage for streamflow augmentation, and the use of forest roads along the river valleys to impound water, creating wetlands that could be used for storage or habitat enhancement</li> </ul>	<ul style="list-style-type: none"> <li>Limited existing hydrogeologic data, shallow bedrock</li> <li>Surface water diversion structure will need to be constructed and maintained</li> <li>A conveyance structure from the diversion point to the recharge area will be needed (abandoned side channel, canal, or transmission main)</li> <li>Lag time between recharge and seepage back to the stream may be too short to provide significant benefits during the desired augmentation period</li> </ul>	Low-Moderate	Low

Note

See Figure 2-X for area locations.

All aquifer materials area glacial and alluvial materials over bedrock, except Beaver/Lake Pleasant, which does not have substantial alluvial material

\* Very few well logs are available in the Ozette/Trout Creek area

TABLE 4-1

City of Forks  
Groundwater Certificates

Control Number	Certificate Number	Local Name	TRS	Priority Date	Primary Qi (gpm)	Supplemental Qi (gpm)	Primary Qa (acre-feet/year)	Supplemental Qa (acre-feet/year)	Depth of Well (ft bgs)	Screened Intervals (ft bgs)
G2-*03542CWRIS	2108-A	Wells 1 & 2	T28N/R13W-04 SW/SE	2/11/1954	500		504		Well 1: 178	125-135
									Well 2: 161	109-113
G2-*05930CWRIS	4120-A	Well 3	T28N/R13W-04 SW/SE	5/2/1961		290		464	Well 3: 114	102-109
G2-24829CWRIS		Wells 4 & 5	T28N/R13W-09 NE/NW	3/15/1978	600		446	504	Well 4: 130	118-128
									Well 5: 132	117-128
Total:					1,100		950			

Note: all certificates are for municipal supply

Table 5-1

Life Cycles of Selected Salmonids

Species	Fresh-Water Life Phase	Month											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Spring Chinook	Upstream Migration												
	Spawning												
	Juvenile Out Migration												
Summer-Fall Chinook	Upstream Migration												
	Spawning												
	Juvenile Out Migration												
Coho	Upstream Migration												
	Spawning												
	Juvenile Out Migration												
Steelhead (Winter)	Upstream Migration												
	Spawning												
	Juvenile Out Migration												

Note: Bull Trout / Dolly Varden - Listed by the US Fish and Wildlife Service under the Endangered Species Act as Threatened  
Limited information available on quantity and distribution of chum, summer steelhead, and lampreys.

Source: A Catalog of Washington Streams and Salmon Utilization; Volume 2: Coastal; Washington Department of Fisheries, 1975.

**Table 5-2**  
**Precipitation Summary**

<b>Month</b>	<b>Owl Creek #1 (Inches)</b>	<b>Owl Creek #2 (Inches)</b>	<b>Maple Creek (Inches)</b>	<b>Nolan Creek (Inches)</b>
January	21.8	21.8	21.7	18.4
February	17.8	17.8	17.6	15.0
March	15.6	15.6	15.6	13.3
April	10.1	10.1	9.9	8.5
May	6.3	6.3	6.2	5.3
June	4.4	4.4	4.4	3.7
July	2.8	2.8	2.9	2.5
August	3.3	3.3	3.3	2.8
September	5.8	5.8	5.9	5.5
October	13.9	13.9	13.9	11.9
November	19.4	19.4	19.4	16.5
December	25.4	25.4	25.2	21.4
<b><i>Annual</i></b>	<b><i>147</i></b>	<b><i>147</i></b>	<b><i>146</i></b>	<b><i>125</i></b>

**Table 5-3**  
**Available Water to**  
**Fill Reservoir**  
 (acre feet)

Month	Owl Creek #1	Owl Creek #2	Maple Creek	Nolan Creek
January	4,682	3,548	1,539	2,006
February	3,831	2,903	1,247	1,636
March	3,340	2,531	1,106	1,451
April	2,170	1,644	704	926
May	1,353	1,025	437	581
June	935	708	312	408
July	592	449	202	271
August	711	539	235	310
September	1,254	950	420	597
October	2,984	2,261	987	1,300
November	4,171	3,161	1,377	1,804
December	5,447	4,127	1,789	2,329
<b><i>Annual</i></b>	<b><i>31,463</i></b>	<b><i>23,842</i></b>	<b><i>10,360</i></b>	<b><i>13,610</i></b>

Notes:

Estimates assume that half of the water quantity is lost to infiltration, evapotranspiration, and flow-through to maintain streamflows.

**Table 5-4**  
**Water Volume Requirements**

Owl Creek #1 - near start of dog leg						
Dam Height (ft)	Reservoir Surface Area (acres)	Reservoir Capacity (AF)	Dam Length (ft)	V/L	Catchment above Dam (sq mi)	Water Available to Fill Reservoir (AF) <sup>1</sup>
40	9.6	384	275	1.4	8.05	31,463
80	16.5	1,044	455	2.3	8.05	
120	34.4	2,419	630	3.8	8.05	
Owl Creek #2 - at the fork further upstream						
Dam Height (ft)	Reservoir Surface Area (acres)	Reservoir Capacity (AF)	Dam Length (ft)	V/L	Catchment above Dam (sq mi)	Water Available to Fill Reservoir (AF) <sup>1</sup>
40	6.3	252	215	1.2	6.10	23,842
80	16.4	908	330	2.8	6.10	
120	32.7	2,216	480	4.6	6.10	
Maple Creek #1 - closest to start of dog leg						
Dam Height (ft)	Reservoir Surface Area (acres)	Reservoir Capacity (AF)	Dam Length (ft)	V/L	Catchment above Dam (sq mi)	Water Available to Fill Reservoir (AF) <sup>1</sup>
40	5.2	208	440	0.5	2.66	10,360
80	16.2	856	585	1.5	2.66	
120	31.4	2,112	740	2.9	2.66	
Nolan Creek #1 - near Mt. Octopus						
Dam Height (ft)	Reservoir Surface Area (acres)	Reservoir Capacity (AF)	Dam Length (ft)	V/L	Catchment above Dam (sq mi)	Water Available to Fill Reservoir (AF) <sup>1</sup>
40	13.5	538	580	0.9	4.09	13,610
80	32.7	1,847	845	2.2	4.09	
120	56.2	4,096	1,025	4.0	4.09	

Notes:

Estimates assume that half of the water quantity is lost to infiltration, evapotranspiration, and flow-through to maintain streamflows.

**Table 5-5**  
**Owl Creek Site No. 1 Volume Comparison**

Water Volume (acre-feet) Needed for a 12-hour Duration Pulse

Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	99	119	149	159	179	198
5	248	298	372	397	446	496
10	496	595	744	793	893	992

Water Volume (acre-feet) Needed for a 24-hour Duration Pulse

Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	198	238	298	317	357	397
5	496	595	744	793	893	992
10	992	1190	1488	1587	1785	1983

Notes:

*40, 80, or 120 foot dam.*

80 or 120 foot dam

120 foot dam

**Table 5-6**  
**Owl Creek Site No. 2 Volume Comparison**

Water Volume (acre-feet) Needed for a 12-hour Duration Pulse						
Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	99	119	149	159	179	198
5	248	298	372	397	446	496
10	496	595	744	793	893	992

Water Volume (acre-feet) Needed for a 24-hour Duration Pulse						
Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	198	238	298	317	357	397
5	496	595	744	793	893	992
10	992	1190	1488	1587	1785	1983

Notes:  
*40, 80, or 120 foot dam.*  
80 or 120 foot dam  
120 foot dam



**Table 5-7**  
**Maple Creek Volume Comparison**

Water Volume (acre-feet) Needed for a 12-hour Duration Pulse

Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	99	119	149	159	179	198
5	248	298	372	397	446	496
10	496	595	744	793	893	992

Water Volume (acre-feet) Needed for a 24-hour Duration Pulse

Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	198	238	298	317	357	397
5	496	595	744	793	893	992
10	992	1190	1488	1587	1785	1983

Notes:

40, 80, or 120 foot dam.

80 or 120 foot dam

120 foot dam

**Table 5-8**  
**Nolan Creek Volume Comparison**

Water Volume (acre-feet) Needed for a 12-hour Duration Pulse						
Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	99	119	149	159	179	198
5	248	298	372	397	446	496
10	496	595	744	793	893	992

Water Volume (acre-feet) Needed for a 24-hour Duration Pulse						
Number of Pulses	Flow (cfs)					
	50	60	75	80	90	100
2	198	238	298	317	357	397
5	496	595	744	793	893	992
10	992	1190	1488	1587	1785	1983

Notes:  
*40, 80, or 120 foot dam.*  
80 or 120 foot dam  
120 foot dam